Managing and displaying different time granularities of clinical information

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ABSTRACT

We approach the need of representing by powerful graphical user-interface the granularity of the temporal clinical information. In this work we present some contributions, to suitably display such temporal clinical information. The graphical representation relies on a temporal clinical data model able to manage data having different granularities.

1. INTRODUCTION

In the medical field, information has often a temporal dimension specified at different accuracy. Furthermore, temporal information can subtend the concept of instant or the concept of interval.
Let consider, for example, the following sentences:

1) "At 17:30 of July 18, 1992, the patient was hit by infarction"
2) "In 1989 the patient suffered from hypertension; hypertension lasted six months"
3) "Starting from June 15, 1989, the patient assumed diuretics for four months"
4) "In the visit of May 24, 1990, the physician measured a systolic blood pressure of 140 mmHg on the patient"
5) "From 17 hours to 19 of March 27, 1989, the patient suffered from abdominal pains"
6) "At 16:30 of October 26, 1990, the patient finished suffering from renal colics; they lasted five days"

Generally the above sentences consist in one atemporal proposition plus an expression specifying the temporal dimension. The atemporal proposition can concern various types of clinical information. The sentences set listed here above shows that clinical information has different sources. For example, it can derive straight from what the patient narrates, from what the physician wrote in preceding medical records, or it can be related to objective data collected during follow-up visits.
In the sentence 1) the instant is specified at the level of minutes, while in the sentence 4) the instant is specified by the unit of measure of days. In the sentence 2) the starting instant is given by the unit of measure of years, whereas months are used for the duration. In the sentence 3) days and months specify respectively the starting instant and the duration of the interval. The sentence 5) specifies, by the unit of measure of hours, the starting and the ending instants of the pathological event. Finally, the sentence 6) specifies by minutes the ending instant of the pathology, whereas it uses days for the duration. Although the physicians do not have any difficulty in performing a human processing of so different temporal specifications, such a variety makes very hard any computer processing.
Medical databases and medical expert systems literature report many contributions approaching the management of temporal clinical information [1, 2, 3, 4]. Recently a need has been emphasized: the **time management at different levels of granularity** [5, 6]. The granularity of a given temporal information is the level of abstraction at which the information is defined [7]. For database systems based on the calendar time, granularity is the unit of measure used for the time scale.
In systems allowing to store and to manage temporal clinical data, the users want displaying the clinical information effectively. A **suitable graphical representation tool** should be the proper answer [8]. The graphical representation should allow to clearly qualify and quantify the temporal dimension of clinical information. Furthermore, the representation should allow to take visually both qualitative and structured comparisons between clinical events themselves [9].
The effort described in this paper deals with defining a graphical representation of the temporal dimension of clinical data, given at different levels of granularity. The graphical representation relies on a temporal data model allowing to manage in a powerful way the temporal dimension of data to be stored in a database [1].

2. THE TEMPORAL CLINICAL DATA MODEL

The aims subtended to the proposed temporal clinical data model are multiple [1]:

- allow to express of the temporal dimension of the clinical information by different and mixed granularities;
- represent and manage the temporal dimension of clinical information in a homogeneous and unified way;
- allow to make operations on temporal dimensions of the clinical information and to establish relations between temporal clinical data;
- manage and model more types of clinical information, identified in the atemporal parts of the above sentences.

2.1. The temporal ontology

The model allows to represent the temporal clinical information by the concepts of *temporal assertion* and of *interval* [1].

Let be *temporal assertion* an assertion composed by a proposition and a temporal interval. Let be E a temporal assertion expressible by the tuple $<E_p,E_i>$: this tuple means that the proposition E_p is true in the interval E_i.

Let be *interval* a closed set of contiguous elementary instants, i.e., instants defined at the level of seconds, specified by the tuple:

<starting instant, duration, ending instant>

This tuple allows to specify the temporal dimension of all the mentioned sentences.

It is possible to define *instants* at various levels of granularity:

years:	*<year>*
months:	*<year, month>*
days:	*<year, month, day>*
hours:	*<year, month, day, hour>*
minutes:	*<year, month, day, hour, minute>*
seconds:	*<year, month, day, hour, minute, second>*

A *duration* can be specified by combining:

years	*months*	*days*	*hours*	*minutes*	*seconds*

Besides these numerical values, a duration can assume two particular values: *undef*, in case it is not possible to determine the duration itself; ε, for duration of one or more orders of magnitude lower than seconds. A couple of *elementary instants* allows to univocally represent both instants and durations. Let be *elementary instant* a temporal point, on the discrete time axis, expressed by the units of measure of seconds, that is the lowest considered in the model.

Two elementary instants identify the upper and lower bound of the set of time points, the instant can coincide with. For instance, the elementary instants, expressed as "6/15/89, 0 hours, 0 minutes, 0 seconds" and "6/15/89, 23 hours, 59 minutes, 59 seconds", univocally characterize the starting instant of the interval of the sentence 3), expressed as "6/15/89". In an analogous way, two distances between elementary instants identify the upper and lower bound of the set of time distances, the duration can coincide with.

2.2. The temporal clinical assertions

The data model defines many temporal clinical assertions. The choice performed in the data model for the atemporal part of the temporal clinical assertions consists in identifying suitable syntactic structures for the different types of clinical information. According to the predefined sentence structure, terminological freedom is given in describing the particular clinical information. The following attributes identify the syntactic structure of the atemporal part of the temporal assertion *diagnosis*:

- *Pathology*: it is the only mandatory part, to make the temporal assertion meaningful. It contains the specification of the pathology, the patient suffered from.
- *Localization*: it specifies the anatomic part, the pathology influenced.
- *Quantifier*: it specifies the strength of the pathology.
- *Specifier*: it enriches the description of the pathology by further details.

Likewise, the following attributes identify the syntactic structure of the atemporal part of the temporal assertion *therapy*:

- *Drug name*: it is the only mandatory part, to make the temporal assertion meaningful. It contains the specification of the drug taken by the patient.
- *Category*: it characterizes the therapy by terms as "Emergency", "Usual Posology", "Maintenance".
- *Quantity*: it specifies the drug quantity of each taking.
- *Unit of measure*: it specifies the unit of measure used to specify the taken drug quantity.
- *Frequency*: it specifies how many times the patient must take the drug in a certain period.

The temporal clinical assertions related to follow-up visits partially differ from those related to anamnestic information, because their atemporal part is usually less structured; it refers to quantitative data coming from measurements performed on the patient. The temporal dimension of all the data collected during a visit coincides usually with the follow-up date. In the model the entity *follow-up visit*, containing a set of temporal clinical assertions with the same temporal dimension given by the entity *interval*, from which the entity *follow-up visit* inherits.

The sentence 4) is an example of a temporal clinical assertion coming from data collected during a follow-up visit. In the same visit other temporal assertion could be present, having the atemporal part as:

Diastolic blood pressure equal to 80 mmHg

or

Heart rate: 88 bpm

3. GRAPHICAL REPRESENTATION OF THE PATIENT CLINICAL HISTORY

During the displaying of the temporal clinical data stored for a certain patient, it is very useful the physician has at disposal a system able to represent, by suitable graphical notation, the temporal dimension of the clinical events belonging to the patient history. This way, the physician obtains a synoptic view of the clinical history of the patient.

The temporal dimension of the clinical events can have different granularities: temporal relations between events cannot always be stated with certainty. Anyway, the graphical representation of the clinical history must allow the physician to establish if some temporal relations between clinical events may exist. For example, if the events "acute myocardial infarction at 17:30, July 28th 92", "taking of acetyl-salicylic acid from August 13th 1992 for 10 months", and "abdominal pains for six months starting from August 1992" compose the clinical history of the patient, the displaying system, by a suitable graphical symbology, should allow the physician to immediately identify the temporal localization and the extension of the intervals related to the three clinical events. In this case, the physician should immediately establish that a) the myocardial infarction is before both the other events, b) the abdominal pains finished before the therapy finished, while c) the abdominal pains could be started before or after the taking of acetyl-salicylic acid started.

We considered various factors in designing the system for the displaying of the patient clinical history:

- representing the granularity of the intervals of the considered clinical events, in respect with the starting instant, the duration, and the ending instant;
- representing the temporal dimension, given by more intervals, of the full clinical history or of a partial history, using all the available space on the screen;
- representing a reference time axis, to give an absolute time location of the clinical events. Many different chronological reference marks should be displayed.

3.1. Design of the graphical symbology

The graphical symbology used to display the intervals allows the physician to easily understand the temporal localization of the considered clinical event. The representation highlights that a starting instant or a finishing instant of an interval can coincide with a generic elementary instant (expressed at the granularity of seconds) belonging to a set of elementary instants, which is related to the used granularity. Furthermore, the representation highlights that a duration of an interval can coincide with a distance between elementary instants, belonging to a set of time distances, which is related to the used granularity.

We introduced ad-hoc graphical symbols to display durations assuming one of the two special values ε or *undefined.* If the duration assumes the value ε, we use a square inside the rectangle representing the starting instant of the interval. Inside the square the character ε, if data concerns therapies or diagnoses, is displayed; in this case, obviously, the extension of the square is predefined and it is not significant of the duration of the interval. A rectangle extending to the upper (lower) bound of the time axis represents the duration assuming the value *undefined.* The label *"undef"* inside the rectangle further highlights this feature.

Fig. 1 depicts some of the graphical symbols used if the duration does not assume one of the two special values ε or *undefined.*

Some border-line situations have been considered: if the temporal extension of a clinical event is too small to be efficaciously on the screen, the horizontal dimension of the rectangle representing the clinical event is forced to be the same of the vertical dimension stated for each symbol.

Finally, suitable labels and colors related to the particular clinical event complete the graphical symbology. If the event is a diagnosis, the label contains the particular pathology occurred in the interval. If the event is a therapy, the label contains the particular drug name taken in the interval. If the event is a follow-up visit, the label contains the name of the physician performed the visit.

4. SYSTEM DESCRIPTION

We implemented and tested the user-interface able to graphically display the clinical history of the patient on a temporally oriented medical record for PTCA patients, which are undergoing to several follow-up visits. For these patients the narrative data have to be updated also during the follow-up period.

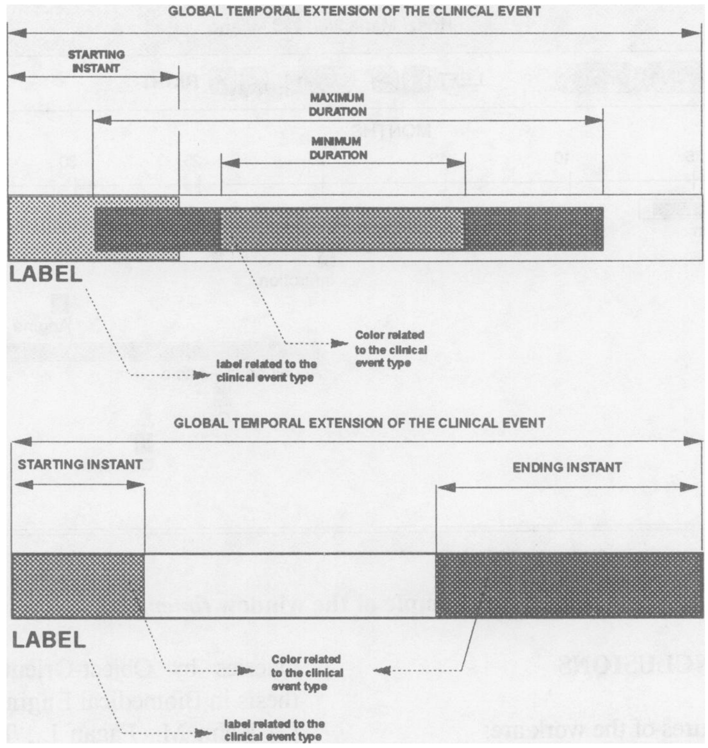

Fig. 1 Graphical symbology for the representation of the temporal dimension of diagnoses and therapies, if the duration does not assume particular values ε or *undefined.*

The figure highlights two capabilities to show a time interval; a further capability allows to show the ending instant and the duration of an interval. In the symbol at the top of the figure the duration is given in an independent way from the starting or the ending instant.

Historical data and follow-up data have to be managed in a global way, to monitor the status of the patient. We implemented the user-interface software on a Unix Sun SparcServer470; we developed the user-interface using OpenLook™ libraries with the C++ language. The clinical data are stored by the OODBMS ONTOS™.

4.1. The displaying system for the temporal clinical data

By the defined graphical symbols the physician can display the temporal dimension of all the clinical data of a patient. The physician can easily perform the displaying of suitable clinical sub-histories; he can add or remove temporal clinical events from the set of the represented ones. For each new selection of the clinical events to display, the bounds of the time axis on the screen are fixed so that the space on the screen is fully used; at the same time all the selected clinical events are completely displayed.

The reference marks on the time axis are stated in respect with the displayed temporal extension. The physician, however, can both move the bounds of the displayed time axis and choose the temporal distance between the reference marks. The physician can also enlarge the representation of the time axis. This way, the selected time axis is not completely displayed: the physician can display the parts of the selected time axis by a scrollbar. Finally, by vertical lines starting from each reference mark it is possible to identify more precisely the location of each represented interval in respect with the others and with the time axis.

The window *timepanel* allows in the Open Windows™ environment to display in a suitable window the clinical history of the patient. The fig. 2 shows an example of the window *timepanel*.

The window *timepanel* has the ID data of the considered patient as title. The window gives many options allowing the user to customize the displaying of the patient clinical history. The button labeled by "*Options*" allows to open a menu having three options labeled by "*Zoom Width*", "*Zoom Height*", and "*Redefine Extreme Instants*", respectively. Finally, on the window *timepanel* some buttons allow to dynamically control the bounds of the displayed time axis. The buttons labeled by ">" and "<", if selected, cause a shift of the lower bound and of the upper bound of the time axis. The button labeled by a time unit allows to choose the step for the shift.

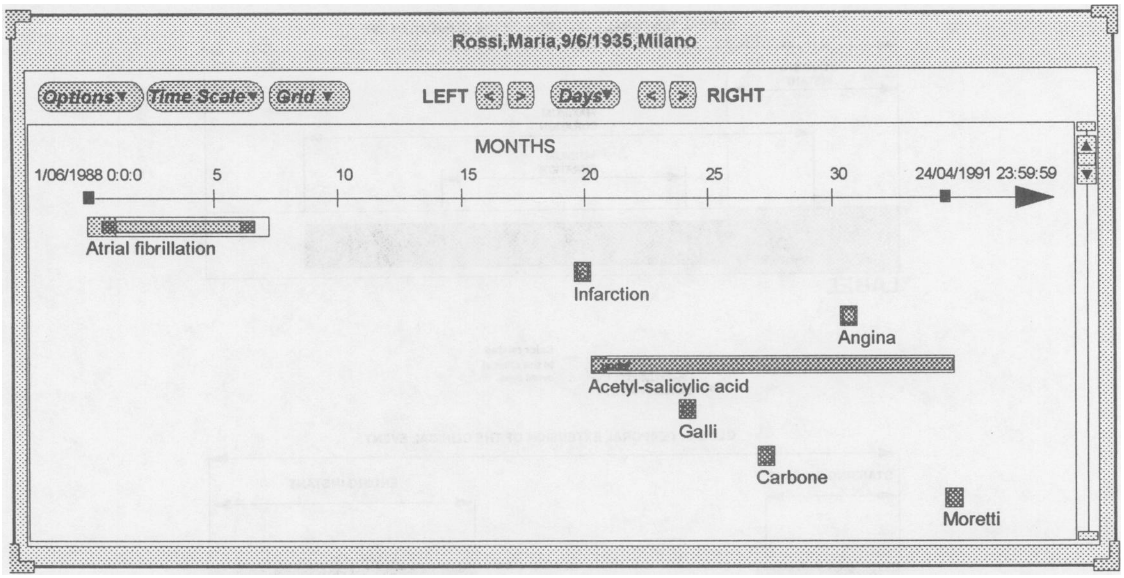

Fig. 2 An example of the window *timepanel*

5. CONCLUSIONS

The most relevant features of the work are:

- **Definition of a temporal clinical data model, to manage temporal clinical information given at levels of granularity**. The temporal clinical data model assumes the *interval* as fundamental concept; it relies for its computational properties on the concepts of *instant* and *duration*. The concept of *temporal assertion* has been introduced, to consider entirely information having a temporal dimension. Temporal clinical assertions have been proposed to manage data related to diagnoses, therapies and visits.
- **Design and implementation of a graphical user-interface able to represent the clinical history of the patient.** We designed and implemented a system able to represent the temporal dimension of the clinical events of the patient clearly and efficaciously. Clinical events with different time granularities compose the clinical history of a patient. We defined a suitable symbology, to manage some types of clinical information; the symbology allows to visually understand the different time granularities of the clinical events.

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